2 or 3 to occur (less than 5% damage expected). At those conditions, collocation induced additional damage would be slight or none at all. However, the facilities are very sensitive to ground movement and there are a number of potential landslide or lateral spread (or liquefaction) locations along the lifeline routes that coincide with MMI = VIII. North of the San Andreas fault the earthquake risk comes predominantly from shaking, but most of the peak shaking intensities are VII with a few isolated locations of VIII.

Another important activity of the data acquisition phase of the study is to divide each lifeline into segments for subsequent analysis. Figures 6 and 7 were used to guide the segmentation process. The communication lifelines were divided into 12 to 14 segments, depending on the route of the individual fiber optic conduits; the electrical power transmission lifelines were divided into four segments (the Arrowhead Calelectric-Shannin line at the southeast corner of the study area was analyzed as a single segment); the natural gas pipeline lifelines were divided into five or eight segments; the petroleum products pipeline lifelines were divided into 10 segments; the railroad lifelines required 30 segments; and the interstate highway required 36 segments. The subsequent vulnerability calculations for the communication, electrical, and fuel pipeline lifelines were performed by hand; those for the transportation lifelines were performed with a standard computer spreadsheet. These approaches recognized the number of calculations that would be required.

5.2 Lifeline Collocation Vulnerability Analysis Results

Figure 7 identifies the locations of the 101 collocations that were subsequently analyzed in this study. These collocations involved over 250 separate potential lifeline interactions. Table 15 was prepared to identify the collocation and the lifelines that were involved at that location. As the collocation evaluation was prepared, the results were tabulated against the index, thus assuring that all potential interactions were located and evaluated.

Table 15 and Figure 7 identify several critical clusters of interactions. With this in mind, a collocation damage scenario was developed for each critical cluster of interaction. Using a standard collocation damage scenario at the critical clusters helped assure the overall consistency of the interaction analyses.

The clusters where the standard collocation damage scenario was used were:

1. The liquefaction zone south of the interchange of I-15 and I-215. There were 10 separate potential interactions involving I-15, railroad bridges, several fiber optic lines, the 16-inch natural gas pipeline, and the 8-inch and 14-inch

Table 15
MATRIX OF LIFELINE COLLOCATIONS AND INTERACTIONS

INTER-SECTION NO.	HIGH-WAYS A B C D E	RAIL-ROADS A B C	POWER LINES A B C D E F	FIBER OPTIC A B C D	NATURAL GAS A B C	PETRO LINES A B
1	X		X X			
2	X			X		
3				X	X X	
4		X		X		X
5	X		X	X X	X	
6		X	X		X	
7		X		X		
8	X				X X	
9				X	X	X
10	X			X		X
11		X X		X		X
12		X X			X	X
13		X				X
14	X	X X				
15				X		X
16						X
17	X			X		
18	X			X		
19	X			X		
20				X	X	
21		X X			X	
22					X	X
23		X		X		
24		X		X		
25	X			X X X X	X	X X
26	X X					
27				X		X
28	X			X X X X		
29	X			X X X X	X	X X

Table 15 (Continued)
MATRIX OF LIFELINE COLLOCATIONS AND INTERACTIONS

INTER-	HIGH-	RAIL-	POWER	FIBER	NATURAL	PETRO
SECTION	WAYS	ROADS	LINES	OPTIC	GAS	LINES
NO.	A B C D E	A B C	A B C D E F	A B C D	A B C	A B
30	X				X	
31		X			X	
32		X X	X X		X	
33		X			X	
34		X			X	
35		X X	X			
36	X		X X	X X X X		X X
37			X		X	X X
38		X X				X X
39				X X X X		X X
40	X	X X	X	X X X X		
41	X	X X	X X	X X X X		
42		X X	X			
43		X	X X			
44	X X	X X	X X	X X X X		
45		X X			X	
46		X		X X X X	X	
47	X	X				
48	X	X X	X			
49	X	X X				
50	X					
51	X X					X X
52		X X				X X
53			X			X X
54		X X	X			
55	X	X		X X X X		
56	X			X X X X		X X
57	X	X X				
58		X X		X X X X		X X

Table 15 (Continued)
MATRIX OF LIFELINE COLLOCATIONS AND INTERACTIONS

INTER-SECTION NO.	HIGH-WAYS A B C D E	RAIL-ROADS A B C	POWER LINES A B C D E F	FIBER OPTIC A B C D	NATURAL GAS A B C	PETRO LINES A B
59	X			X X		X X
60	X			X X		X X
61			X	X X		X X
62	X X		X	X X X X		
63			X		X	
64			X		X	
65			X		X	
66	X				X X	
67		X X X			X X	
68		X X			X	
69	X		X			
70	X		X			
71	X		X			
72		X	X			
73		X	X			
74		X	X			
75		X	X			
76		X X X	X			
77		X			X	
78	X				X	
79			X	X X		X X
80			X X		X	
81	X		X	X X		
82		X	X			
83	X	X		X X		
84		X	X X		X	
85		X	X X			
86		X	X			
87			X X X	X		

Table 15 (Continued)
MATRIX OF LIFELINE COLLOCATIONS AND INTERACTIONS

INTER-SECTION NO.	HIGH-WAYS A B C D E	RAIL-ROADS A B C	POWER LINES A B C D E F	FIBER OPTIC A B C D	NATURAL GAS A B C	PETRO LINES A B
88				X X	X	X X
89		X		X X	X	X X
90		X	X			
91	X				X	
NOT USED						
93	X					
NOT USED						
95				X	X X X	
96		X			X	
97		X			X X	
98			X		X	
99			X		X	
100			X		X	
101			X X			
102	X				X	
103			X		X	

petroleum products pipelines. All of the buried lifelines were found to have incurred damage state 7 (catastrophic) with probabilities that the damage occurred of 40%. The assumed collocation interaction was that the petroleum pipelines could drain 1-2 miles of pipe but that no secondary fires or explosions would occur. This contributed to an additional 30 day delay to the site before repair could commence, due to the requirements to assure that fire conditions and environmental concerns could be alleviated before work could start on the individual lifelines. An additional 10 days of delay were hypothesized due to the need to coordinate the work on so many individual lifelines.

2. A second cluster exists along the Cajon Blvd. extension into the Cajon Pass from north of the I-15/I-215 interchange to Blue Cut. There are two separate locations where

landslides (with a probability of occurrence of 45%) and two liquefaction areas (probability of occurrence of 20% and 40%) are possible, including eight separate collocation impact areas where there are collocated power lines, railroads, and a natural gas pipeline. At the two landslide areas along the Cajon Blvd. extension (which was the prior highway 66 before I-15 was built), a natural gas pipeline and the railroads are located at the toe of the slide area, and landslide debris is expected there. Debris removal for clearing the railroad would be required before work on the pipeline (which is located in the railroad right-of-way and sometimes under the rail bed) could begin. The debris removal was assumed to cause a 30 day delay before work on repair of the pipeline could occur.

3. At Blue Cut itself there is another landslide and liquefaction zone. Due to its proximity to the San Andreas fault rift zone, a 70% probability of occurrence was estimated. At that location, a power line, a natural gas pipeline, and a railroad are in the flow area of the slide, which could cause the pipeline to surface and rupture as well as to be covered with debris. The collocation damage scenario assumed that an explosion and fire could result, increasing the damage to the power line and its repair time by an additional 20 days, compared to the delays described for the other slide area, to repair the more extensive damage the fire caused. The potential for landslides blocking the Cajon Creek with a slide dam, and the subsequent impact on downstream lifelines if the dam should catastrophically fail were considered to be outside the scope of this study. At Blue Cut itself, the liquefaction zone has a 50% probability of occurrence.

4. In the San Andreas fault rift zone there are six collocation points that involve the power lines, the railroads, the fiber optics, a natural gas pipeline, the two petroleum products pipelines, and the Cajon Blvd. extension. Fuel spills are assumed to require a 30 day delay for alleviating environmental and fire concerns. An additional 60 day delay was assumed for the petroleum products pipelines because the estimated extensive damage to their right-of-way along the fault trace will require regulatory review and acceptance before the pipeline can be worked on. An additional 30 day delay for the other lifelines was assumed because of the general congestion in the area. Since the fault displacement causes catastrophic failure of the lifelines, the collocation damage scenario does not assume any further damage.

With these scenarios in mind, the collocation vulnerability analysis was performed for each separate lifeline system.

Communication Lifelines

Figure 9 shows the communication lifeline routes in the study area. The location of the photographs presented in this section of the report are also shown on the figure. The microwave, radio, and cellular phone communication towers are sited such that they are not collocated with other lifelines. Thus, they do not enter into the analysis of the impact of collocation. The impact of degraded communications (if these towers should fail) on the ability to restore the other lifeline systems to acceptable delivery conditions is beyond the scope of the present study.

There are five fiber optic systems located in the study area. They include American Telephone and Telegraph (AT&T), Continental Telephone (Contel), MCI Communications (MCI), WTG West (WTG, formerly WilTel), and US Sprint.

The individual fiber optic cables are multi-layered with an inner structure that allows the cable to be pulled and maintained in a state of tension without placing tension on the individual glass fibers. This assembly is then wrapped with various insulating materials, including a metal sheath. In the fall of 1986, the U.S. Forest Service provided MCI and WTG right-of-ways on the basis that they would each provide two conduits and that each conduit would be four inches in diameter so that cables from two different systems could be placed in each individual conduit (thus, provisions were made to lay eight cable systems along the two routes through the Forest Service land). Furthermore,the Forest Service required that the routes be combined as quickly as practical. Thus, the MCI and Contel systems enter the study area from the north along Baldy Mesa Road, while the AT&T, WTG, and US Sprint systems enter from the north along the access road to I-15. The routes join together just south of the separation of I-15N and I-15S (about 1.8 miles north of the Cajon Junction of I-15 and Highway 138). From there they travel together as a bundle of four conduits. Much of their route is along the Cajon Blvd. extension where they are laid in the median strip. Also routed along much of the median strip are the two petroleum products pipelines (the Cajon Blvd. extension was the former divided highway 66, but only the western two lanes are still maintained for traffic). For the purposes of this study, the fiber optic cables are analyzed as buried conduits. Because of their collocation, if one conduit fails, all fail.

When the conduits (which are normally buried) are routed to a bridge location, they are generally brought to the surface and hung with light anchors from the bridge. Figure 10 shows them on a typical bridge crossing on the abandoned portion of Highway 66; Figure 11 shows some of the details of the bridge hangers and the conditions of the conduits; Figure 12 shows them hung from a highway culvert wall just south of Cajon Junction; Figure 13 shows some of the details of the wall anchors near the culvert location of Figure 12. Just south of the culvert shown in Figure 12 the

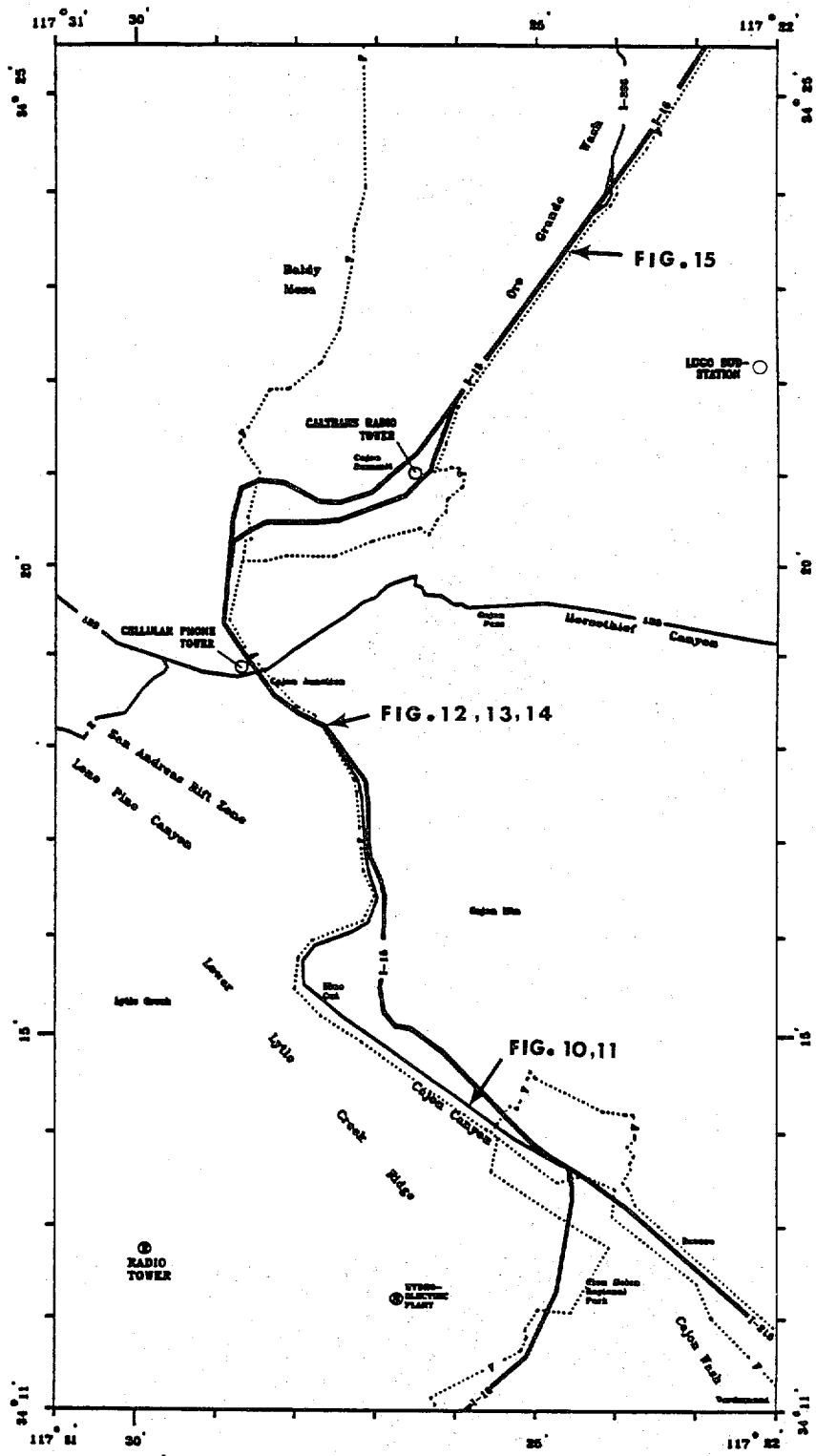

Figure 9 COMMUNICATION LIFELINE ROUTES

Larger Scale Figure Located at End of Document